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ABSTRACT

Scaffolding refers to the instructional support that instructors or more skillful peers offer learners to bridge the gap between their current skill levels and the desired level. An aspect of scaffolding that is often ignored is the fading of support as the learner masters the skill. It has been suggested that there is a risk of over-relying on the support of integrated media in computer-assisted instruction. A three-dimension (3-D) model of scaffolding that incorporates level of subtask, level of support, and number of repetitions of practice has been proposed to vary the technology support systematically in response to the learner's performance. The 3-D contingent scaffolding model was implemented in a computer-based instructional program for statistics called "Hypothesis Testing--the Z-Test" in order to establish baseline data for integrated media-based instruction or a hypermedia learning environment. The scaffolded instruction as evaluated in terms of knowledge maintenance and transfer by comparing it to full-support instruction and least-support instruction. Findings from 75 college students provide evidence that the scaffolded computer-based instruction promoted knowledge maintenance and improved independent knowledge application, while promoting learning consistently across individuals. Results also show that a dynamic measure of the learner's ability is a better predictor of the learning outcome for subjects using this scaffolded instruction than static measures. The model provides a systematic way to link the concept of scaffolding to integrated media design features using both support building and support fading techniques. (Contains 2 tables, 6 figures, and 17 references.) (SLD)

Scaffolding in a Computer-Based Constructivist Environment for Teaching Statistics to College Learners

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ABSTRACT

To prevent the user from over-relying on technology support, the researchers proposed a 3-D contingent scaffolding model to systematically vary the technology support in response to the learner's performance in a learning task consisting of a sequence of sub-tasks. The research reports on the implementation of this model in a computer-based instructional program on a topic in statistics and a study of its effectiveness with college students.

In this study, the 3-D contingent scaffolding model was implemented in a computer-based instructional program, "Hypothesis Testing-- the Z-Test," in order to establish baseline data for integrated-media-based instruction or a hypermedia-based learning environment. This scaffolded instruction was evaluated in terms of knowledge maintenance and knowledge transfer by comparing it to full-support instruction and least-support instruction. A secondary interest was to determine whether the predictive utility of static (what the learner already knew) and dynamic (the learner's ability to learn) measures of learners' ability varied in different instructional conditions. The dynamic measure was indicated by the percentage of successful trials in the learning process. The static measures involved seven baseline variables: courses taken, self-rating of skills, and self-rating of preference in mathematics/statistics and pretest.

The findings showed evidence that the scaffolded computer-based instruction promoted knowledge maintenance and improved independent knowledge application. The scaffolded instruction promoted learning consistently across individuals. However, further investigation and evidence is needed to confirm its superiority on knowledge transfer. The results also revealed that the dynamic measure of the learner's ability was a better predictor of the learning outcome for subjects using this scaffolded instruction than the static measures. In media-assisted instruction, the 3-D contingent scaffolding model provided a systematic way to link the concept of scaffolding to the integrated media design features using both support building and fading techniques. In statistical education, this model was implemented successfully on the topic of hypothesis testing. The results of this study also showed that this topic could be taught to college students with low mathematical background and statistics beginners.

INTRODUCTION

The term "scaffolding" has been used to describe various instructional techniques for use in learning activities that reflect authentic task situations. This technique has also drawn great attention from the media researchers for media can provide a more realistic learning environment with rich and varied support. One major concept of this technique is to enable the learner to engage in out-of-reach activities; having a "knowledgeable other" or "more capable peer" to bring the learner along; having something or someone "share the cognitive load" (Jackson et al., 1995). However, if we go back to Bruner's original definition of scaffolding (Bruner, 1983), we find there is another valuable key concept of this technique that has usually been neglected. That is, this knowledgeable or more capable other is not only responsible for building the support in learning activities, but also is responsible for fading the support as the learner gradually masters the skill. The Cognition and Technology Group at Vanderbilt University (1993) has proposed a risk of over relying on the support of integrated media. To educate individuals to be independent and active learners, there is a need to emphasize the support-fading component of scaffolding while we try to integrate this instructional technique into media assisted instruction.

BACKGROUND

Method of Scaffolding

In the past 20 years, the constructivist paradigm has gradually come to educational research. From the constructivist perspective, the purpose of education is to cultivate independent and self-directed learners. Bruner's metaphor of scaffolding provides an explicit strategy to direct our teaching toward this end.

Scaffolding refers to the interactional support that instructors or more skillful peers offer learners to bridge the gap between their current skill levels and a desired skill level. In the process, the amount of support is gradually withdrawn as the learners become more proficient. Ultimately, the learners can complete tasks on their own (Greenfield, 1984). The literature review suggests that scaffolding can enhance comprehension, improve independent learning and application, and promote knowledge transfer (Bruner, 1983, Greenfield, 1984, Cazden, 1988). Evidence of these advantages has been found in many studies in the field of language and cognitive development (Boyle & Peregoy, 1990; Day & Cordon, 1993; Gallimore, Tharp, & Rueda, 1989; Smolucha & Smolucha, 1989).

At the same time, limitations of scaffolding have also been pointed out. This technique has been criticized for its lack of discussion concerning development of the expert's role in providing the novice with assistance (Gaffney & Anderson, 1991). Its implementation has also been criticized for not being able to capture the challenge of responding to the diversity of children's intentions in classroom teaching (Dyson, 1990).

Scaffolding in Computer-Based or Integrated-Media-Based Instruction

Computers have introduced unprecedented levels of autonomy into education. The processing and integrating capabilities of computers can create a realistic, interactive, support-rich, and individualized learning environment. These characteristics may overcome the limitations of scaffolding and ease the implementation of this instructional technique. Several researchers have developed scaffolded computer-based instruction, integrating more than one medium to support learners' knowledge construction in authentic learning activities (Jackson et al., 1995; Steiner & Moher, 1994). However, the discussion has focused mainly on the software development and the support-building models. Only a small amount of qualitative evaluation data have been reported. The support-fading element of scaffolding was not applied in these studies. Therefore, scaffolded instruction has been not only difficult to build, but also extremely difficult to evaluate.

Lieberman and Linn (1991) contended that scaffolding is one of the several ways computers can be used to encourage students to be self-directed. This can be attributed to the support-fading characteristic of scaffolding. However, to use this skill, the major challenge is to determine when the support should be faded and how much the support should be reduced at the time. This requires us to ascertain the learner's mastery level at any point of the scaffolded learning process.

LINKING SCAFFOLDING TO INTEGRATED-MEDIA DESIGN FEATURES

In this research, we sought an operational definition of scaffolding. Based on the definition, we proposed a 3-D scaffolding model which provides a systematic way to apply scaffolding in computer-based or integrated-media-based instruction.

The Elements of Scaffolding Relevant to Integrated-media Design

To link the concept of scaffolding to computer-based instruction (CBI) design features, it is important to identify some basic elements of scaffolded instruction which are especially relevant to CBI design. To illustrate the features of those elements, the metaphor of an adult aiding a toddler (Cazden, 1988) will be used as an example.

1. Hierarchical component skills

In the metaphor of scaffolding, the acquisition of skill is conceived as a hierarchical program in which component skills are combined into "higher skills" by appropriate orchestration to meet new, more complex task requirements (Bruner, 1973). Therefore, the crucial task in scaffolding often possesses a variety of relevant components (usually in an appropriate serial order) necessary to achieve a particular end. It is the instructor's responsibility to decompose the final task into hierarchical component skills based on the nature of the task and the learner's ability. In the example of an adult aiding a toddler, the child must learn how to balance on his feet before taking his first step, must learn how to balance on his first step before stretching out for the second.

2. Decreasing support levels

Scaffolding emphasizes the support that the instructor can provide the learner to reach beyond his/her current skill level. The highest level of support is the situation where the instructor completes the task as a demonstration and the learner takes no responsibility for the current task. The lowest level of support is the situation where the instructor takes no responsibility for the task and the learner completes the task on his/her own. Between the highest and lowest level of support, the instructor shifts a part of the responsibility to the learner by reducing the amount of support one level at a time. In the sense of support withdrawn, the instructor must recognize what kind of support is crucial in the learning and classify the support into decreasing levels. In the example of an adult aiding a toddler, the levels of support could be: helping by holding two hands, helping by holding one hand, helping by holding one finger, etc.

3. Repetitive authentic practice

The scaffolding should be performed in the context of the practical work environment. In the environment, the learner can practice by taking part in the expert behavior in a realistic setting. Each practice involves a full performance of the task. Besides, the underlying structure of the practice must be repetitive so the experience at one point in task mastery could potentially be applied to later activity. Therefore, the instructor has to set up a sequence of authentic practice involving the performance of the same skills.

In the walking example, the child actually experiences the practical task, walking. The practice of walking involves the same component skills and the practice can be repeated in different realistic settings: walking on carpet, walking on solid ground, walking on sand, and so forth.

4. Ongoing assessment

In the process of scaffolding, the support level should be adjusted based on the learner's current skill level. Therefore, the instructor must measure the learner's progress against the global picture of the task and make corrections when needed. Usually, the completion of each component skill is the right time for a progress assessment. In the walking example, the adult observes and measures the child's progress with each baby step. If holding one hand of the child doesn't keep his balance, the adult gives him the other hand right away. If the child walks well by holding one hand, the adult will consider letting him walk by holding only one finger.

Therefore, an operational definition of scaffolding could be as follows. The instructor or the more skillful peer decomposes the task into hierarchical sub-tasks, classifies the amount of support in decreasing levels, and sets up repetitive authentic practice. The practice begins with the highest level of support and the lowest level of sub-task. With the completion of each sub-task in the practice, the instructor measures the learner's performance and judges the level of support he/she should provide and lets the learner perfect the component sub-task that he/she can manage.

The Three-Dimension Contingent Scaffolding Model

Wood et al. (1976) and Day and Cordon (1993)'s studies have suggested the "contingent scaffolded instruction," emphasizing the addition of a pattern of responses for the withdrawal of the support. The pattern involves characterizing the instructor's intervention by the level of abstractness and varying the level systematically in response to the learner's performance. Based on the first two elements of scaffolding discussed above, there are two types of intervention that the instructor can provide in scaffolded instruction. The first type involves the control of the task complexity by simplifying the task itself. The second type involves the control of the task complexity by providing additional support. Most studies (Day and Cordon, 1993; Wood, Bruner, & Ross, 1976; Wood, Wood, & Middleton, 1978) have focused on the second type of intervention. In this study, the researchers proposed a 3-D contingent scaffolding model, considering both types of interventions to apply the contingent scaffolded instruction in a learning task consisting a sequence of steps.

Figure 1 is a graphic illustration of this model for a target task consisting of 4 hierarchical sub-tasks and 4 levels of support. The first two elements of scaffolding actually describe 16 intervention patterns that the learner might encounter at any time depending on the learner's current skill level. The process of scaffolding starts with the completion of the full task (from sub-task 1 to sub-task 4) at the highest level of support (support level 1) and ends with the completion of the full task at the lowest level of support (support level 4) through a sequence of repetitive authentic practice, the third element of scaffolding. The whole process of scaffolding is performed according to the following rules.

1. Each practice involves a full performance of sub-tasks from the first to the last.

2. The first practice starts with the highest level of support. After that, each practice starts with the level of support which is one level lower than the latest one used in the previous practice.

3. At the current level of support, the learner has the chance to work on the following sub-tasks unless he/she encounters any difficulty.

4. In each sub-task of the practice, if the learner encounters any difficulty, the support level is increased by one until reaching the highest level.

The fourth element of scaffolding, ongoing assessment, is actually embedded in the rule 4. To see if the learner encounters any difficulty, an ongoing assessment must be performed at the end of each sub-task.

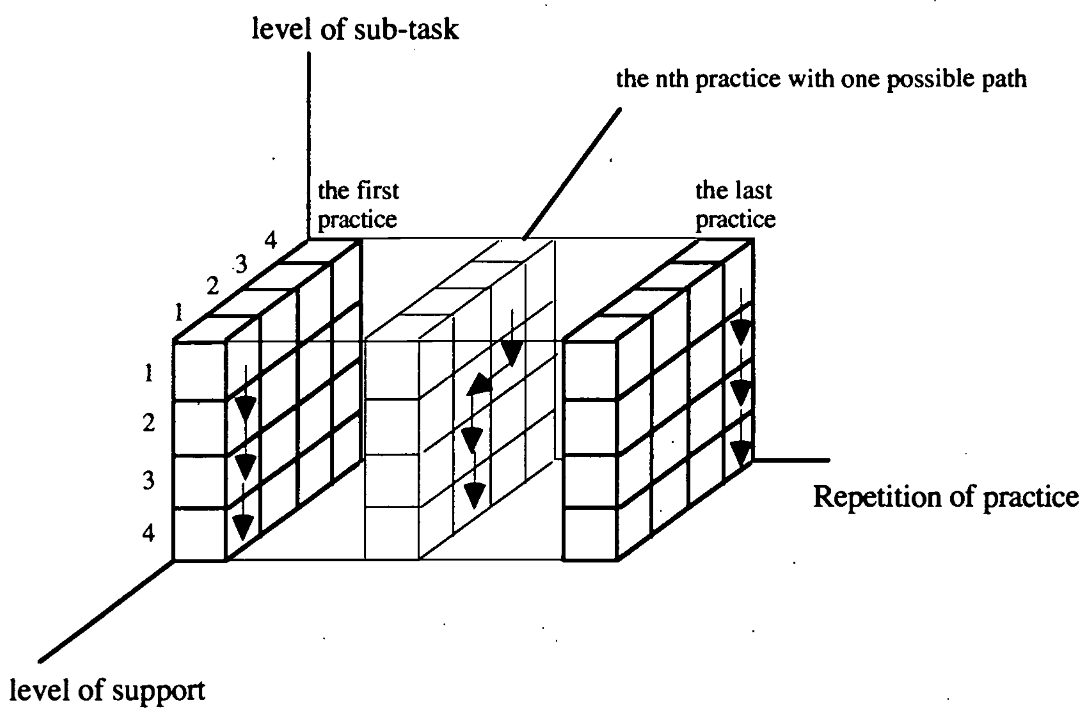

Figure 1. Graphic illustration of the 3-D contingent scaffolding model.

This model of scaffolding describes the learning process as a journey in the space of the three dimensions: level of sub-task, level of support, and number of the repetition of the practice. The first practice is presented as an example in which the instructor takes full responsibility for the task (full support is provided). The last practice is a completely successful examination where the learner takes the full responsibility of the task (the least support is provided). Any practice in between either is an unsuccessful performance or a successful performance but with some level of support. Along the path of the journey, each cubic block is a unit of assessment of the learner's progress. Since this model applies scaffolding in a systematic way, it is especially useful for the computer or integrated media based instruction.

AN EXAMPLE OF IMPLEMENTATION: "HYPOTHESIS TESTING-- THE Z-TEST"

Based on the 3-D model, the software, "Hypothesis Testing-- the Z-test," was developed. In this section, we describe the program, "Hypothesis Testing-- the Z-test," and explain how the 3-D scaffolding model was implemented in this program.

The Motivation of the Task

Statistics is interesting and useful because it is a means of using data to gain insight into real-world problems. However, almost every statistics beginner experiences difficulties understanding the topic. Almost every statistics instructor admits that it is not an easy subject to teach.

As the continuing revolution in computing relieves the burden of calculating and graphing, there is an emerging consensus among statisticians that statistical education should focus on data and on statistical reasoning rather than on either the presentation of as many methods as possible or the mathematical theory of inference (Moore and McCabe, 1993). This consensus has the following influence on statistical education.

1. Applied Statistics should be taught in the context of real-world problems.

Statistics takes real life patterns in real life phenomena and tests them quantitatively. Bridging the gap between reality and numbers is the hardest part. Not all numbers are data. The number 10.3 acquires meaning only when we are told that it is the birth weight of a child in pounds or the percent of teenagers who are unemployed. That is the context that makes the numbers meaningful. Therefore, the examples and exercises should be presented in the context of real-world problems.

2. Applied Statistics can be taught to an extremely diversified audience.

Because the statistics is useful for scientific investigators in many fields, the students sitting in a introduction course of applied statistics might have varied background. However, if the student has no fear of statistics, wants to learn, and possesses a certain amount of mathematical maturity, the varied backgrounds need not detract from the success of the course. In fact, many times this diversity may make students recognize similarities among problems from different fields of application. This gives them a broader scientific approach to statistical problems than providing them only with familiar examples.

3. Applied Statistics can be taught at a low mathematical level.

Since it is the statistical reasoning that should be focused upon instead of the statistical computation, even students with low mathematical level can learn statistics. Therefore, the students of applied statistics can range in mathematical competence from Ph.D. candidates in mathematics to students who have had only high school algebra. Actually, the learners need only a working knowledge of algebra. Being able to read and use formulas would be enough.

4. Applied Statistics can be taught through the applications of a set or a sequence of rules.

Applied Statistics is actually the application of a sequence of rules or principles which is set up based on certain mathematical proofs or the experience of prior statistical experts. The learners do not have to understand the mathematical proof behind each rule. However, it is important for them to understand the expert reasoning behind those rules. It is not only logical but also conceptual. To understand the statistical reasoning, the learner has to work and communicate with the expert to carry out the rules in realistic problems.

Based on the above discussions, we decided to develop a scaffolded computer based instruction in the context of teaching basic applied statistics. The very basic test of statistical hypothesis testing, the Z-test, was selected. The task was selected with several objectives in mind. First, it had to be challenging to the learner while also proving sufficiently complex to ensure that his/her comprehension and problem-solving skill over time could develop. Second, it had to be "feature rich" in the sense of possessing a variety of relevant components. Third, its underlying structure had to be repetitive so the experience at one point in task mastery could potentially be applied to later activity.

This subject matter involves a sequence of problem solving steps and decision making. It naturally provides the chance for assessing users' ongoing learning as well as scaffolding through program support. Therefore, the program instruction is presented as a series of problems involving applying the Z-test.

Implementing the 3-D Contingent Scaffolding Model in "Hypothesis Testing-- the Z-Test"

Table 1 summarizes the four elements of the scaffolding model and briefly describes how each was implemented.

Table 1

Elements of Scaffolding and "Hypothesis Testing-- the Z-Test" CAI Design Features

Elements of Scaffolding	CAI Design Features
1. Hierarchical component skills	Four serial steps to carry out the Z-test
2. Decreasing support levels	Four levels in amount of support
3. Repetitive authentic practice	Up to 20 authentic problem scenarios
4. Ongoing assessment	Performance is judged at the end of each step

1. Hierarchical component skills
   According to the common practice of hypothesis testing, the program decomposed the task into four sub-tasks: state the hypotheses, find the critical value, compute the test statistic, and make the decision.

2. Decreasing support levels
   In considering the support which can be provided via integrated-media and the nature of the task, three types of support were selected to be used in the scaffolded instruction. From concrete to abstract, the three types of support were: visual support, verbal support, and symbolic support.

   The actual environment of the lesson is displayed in Figure 2. It shows how the visual, verbal, and symbolic support appeared on the program screen.

   1. Problem Area
      The Problem Area showed the current problem scenario that the student was working on.

2. Instruction Area
   The Instruction Area provided the instruction or hints to solve the current step of the problem. It functioned as the verbal support.
3. Figure Area
   The Figure Area illustrated the current step of the problem in a graphic form based on the learner's selection of the answers. That was where the visual support took place.
4. Answer Area
   The Answer Area provided the answer or requested the learner to provide an answer for the current step after prompting with symbolic support.

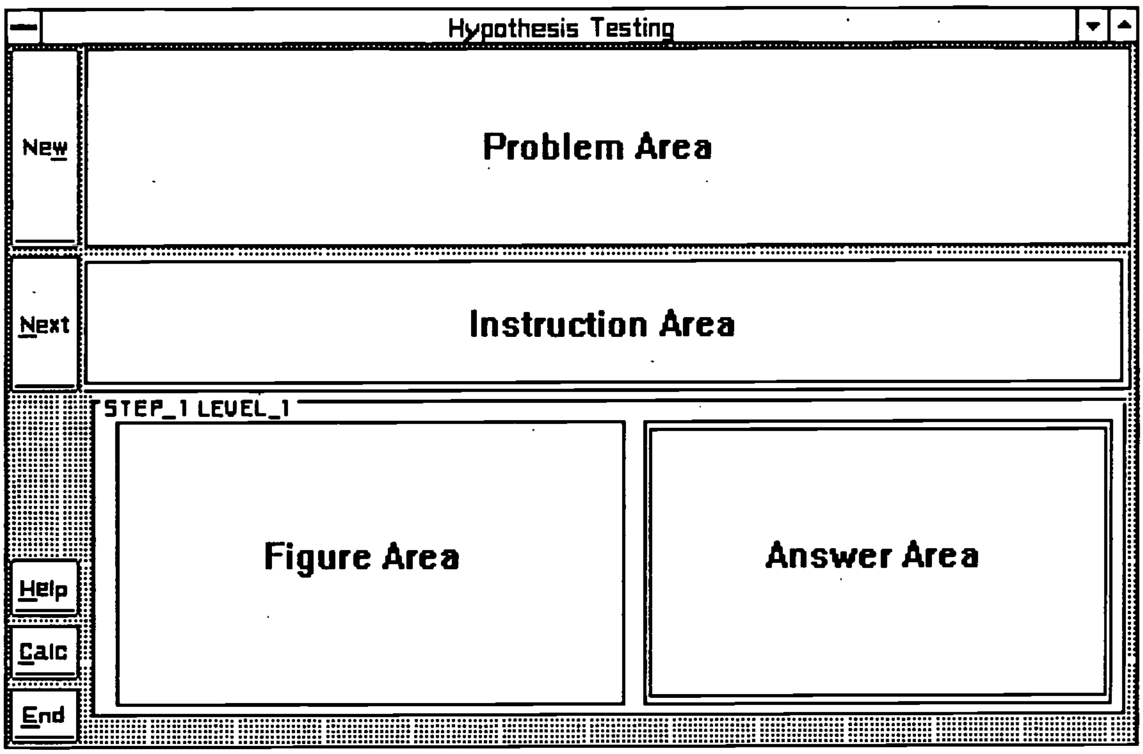

Figure 2. The environment of the lesson.

Based on the three types of support described above, the levels of support can be classified and ranked by the amount of support (how many types of support) provided at the time. These are described below. From level 1 to level 4, the next most concrete type of support was withdrawn from the previous level of support.

Level 1: *Full Support*
The instruction demonstrated the steps to solve the problem in detail with visual, verbal, and symbolic information. Figure 3 is an example of the full support screen.

Level 2: *Visual, Verbal, and Symbolic Support*
Instead of providing the answer with detailed explanation, the instruction only provided the visual and verbal hints to the current problem step and requested the learner to give the answer after the symbolic prompts. An example of the screen with level 2 support is provided in Figure 4.

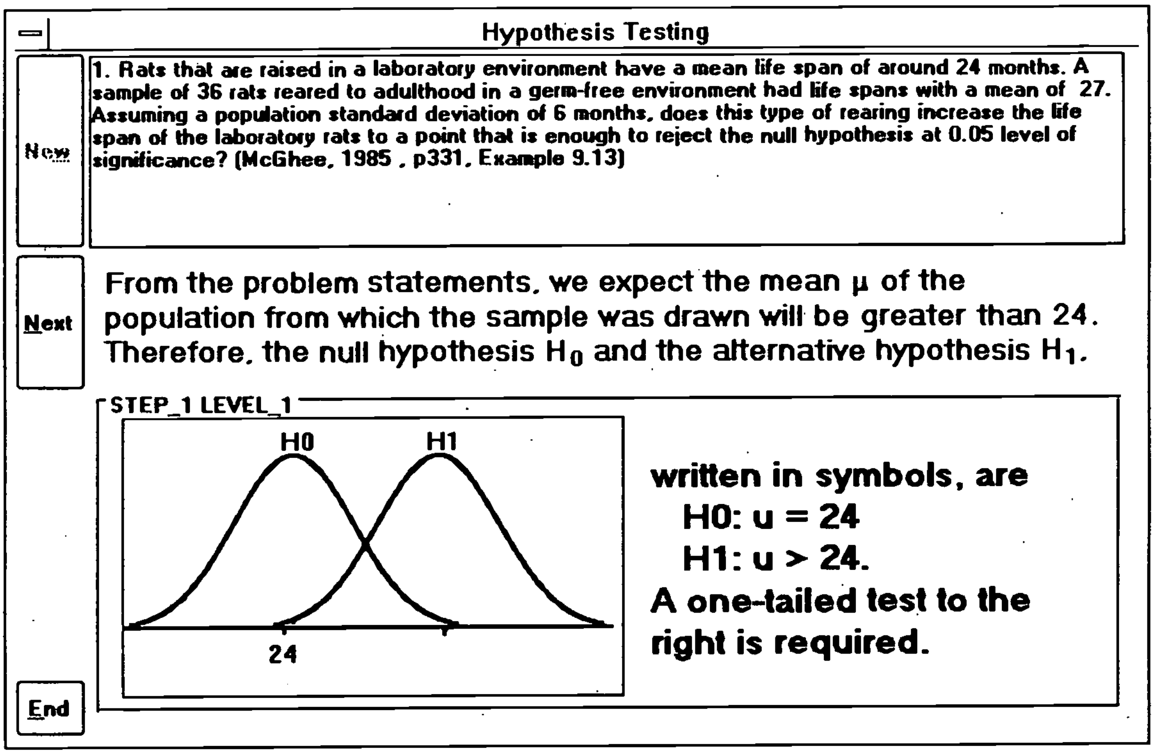

Figure 3. An example screen with level 1 support.

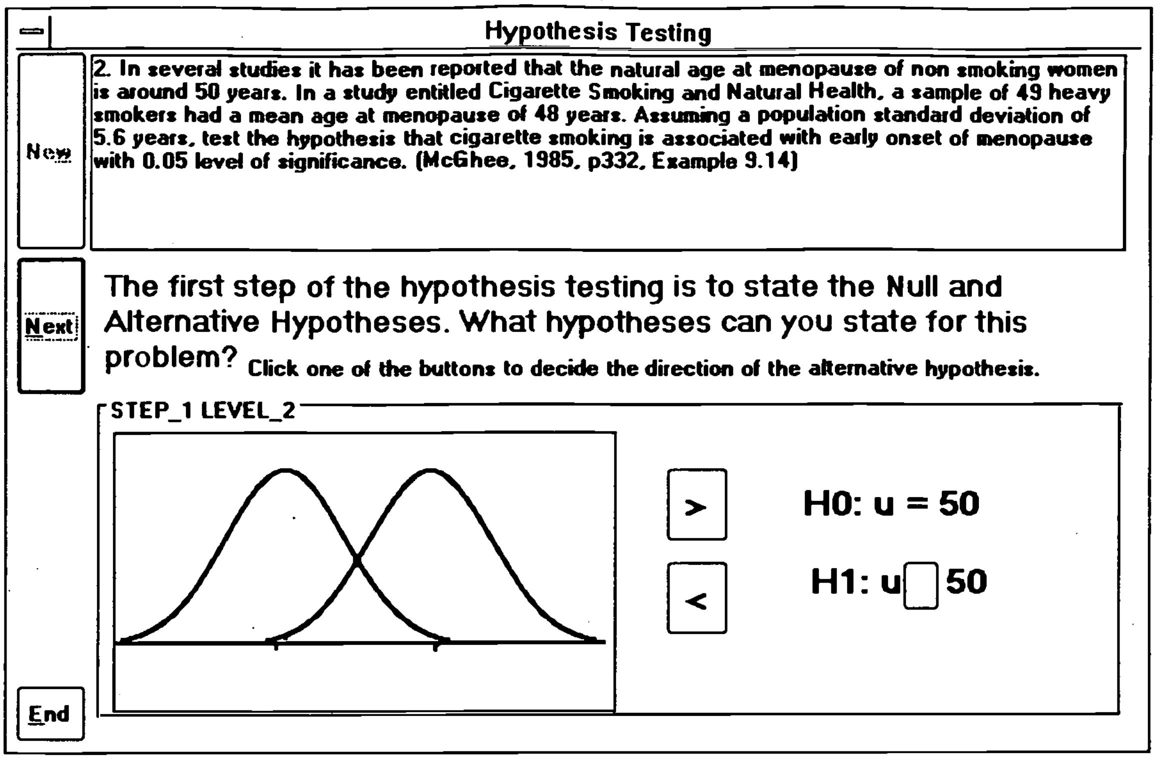

Figure 4. An example screen with level 2 support.

The Figure Area in Figure 4 shows an initial form of the graphic illustration of the current step, Step 1. Based on the learner's selection of the answers, the corresponding information was added to the graph.

Level 3: *Verbal and Symbolic Support*
The information in the figure area disappeared. Only the verbal hint was provided, telling the learner some specific information to look for and asking him/her to provide answers after the symbolic prompts.

Level 4: *Symbolic Support*
The instruction took away the next most concrete support from the screen. Therefore, only the symbolic prompts were provided and the learner was required to give the answer.

3. Repetitive authentic practice

The problems were adapted from many statistics text books, covering the real problems occurring in many disciplines: agriculture, biology, engineering, pharmacy, business, and the social sciences.

4. Ongoing assessment

At the end of each step, the learner's answer was judged for correctness. This judgment decided the next intervention pattern the learner was to encounter.

This specific scaffolded computer-based instruction, "Hypothesis Testing-- the Z test," was expected to be an effective and powerful instructional program, inheriting the advantages and minimizing the limitations of scaffolding. In this study, this scaffolded instruction was evaluated in terms of knowledge maintenance and knowledge transfer by comparing it to the full-support instruction (in which the full support was available all the time), and the least-support instruction (in which only the symbolic support was provided). A secondary interest was to determine whether the predictive utility of static (what the learner already knew) and dynamic (the learner's ability to learn) measures of learners' ability varied in different instructional conditions.

EVALUATION OF "HYPOTHESIS TESTING-- THE Z-TEST"

"Hypothesis Testing-- the Z-Test" was evaluated to address the following research questions:

The effect of the instructional method:

- Would the availability of full support in the computer-assisted learning hamper learners' independence in knowledge application?
- Would scaffolded instruction enhance knowledge maintenance in a computer-assisted learning environment?
- Would scaffolded instruction promote knowledge transfer in a computer-assisted learning environment?

The effect of the static measure of the learner's ability (what the learner had already learned):

- Would learners' background, confidence, and preference in statistics and mathematics influence their knowledge maintenance and transfer?

The effect of the dynamic measure of the learner's ability (the learner's ability to learn):

- Would the learners who showed higher ability to learn in the problem-solving process maintain and transfer the strategy better?

The relationship between the static/dynamic measure and the instructional methods:

- Would the predictive utility of static measure (what the learner had already learned) and dynamic measure (the learner's ability to learn) vary in the three support conditions: scaffolded, full support, and least support?

The relationship between the static measure and the dynamic measure:

- Would learners' prior knowledge influence their learning ability in the task?

The Experiment

Research Design

Based on the research questions described above, a baseline-posttest control group design was implemented using the computer program, "Hypothesis Testing-- the Z-test." The research questions regarding the main effects of the instructional method, the static measures of the learner's ability, and the dynamic measure of the learner's ability were examined under a regression model (more specifically, an analysis-of-covariance model). The research questions regarding the relationships between each other of the three major variables were examined using partial correlation and correlation analyses.

Regressor Variables

There were three types of the regressor variables involved, representing the three different interests of the study.

1. Treatment Variable-- Support Condition

The effect of this type of variable was the major interest of this study. It was manipulated by the computer-based instruction. The design framework of the scaffolded computer-based instruction program, "Hypothesis Testing-- the Z-test," was discussed in detail in the previous section. Part of the design framework is reviewed here:

From concrete to abstract, the three types of support used in the program were visual support, verbal support, and symbolic support. The levels of support were classified and ranked in the amount of support (how many types of support were provided at the time). From level 1 to level 4, the next least abstract type of support was withdrawn from the previous level of support. They were:
Level 1: Full Support;
Level 2: Visual, Verbal, and Symbolic Support;
Level 3: Verbal and Symbolic Support; and
Level 4: Symbolic Support

Based on the design framework, the program was created in a powerful and flexible programming language, Visual Basic 3.0 for Windows. In order to evaluate the effectiveness of this scaffolded instruction, two versions with different non-scaffolded support conditions were adapted from the original program, one with the full-support condition and the other with the least support condition. The three different instructional conditions are described below.

Scaffolded Condition (adjusted level of support among 1, 2, 3, and 4 in an orderly fashion depending on the learner's current ability)
Based on the four levels of support, the program started from the level of full support. The amount of support was reduced by one level in the next problem as the user demonstrated the ability to solve the present problem at the current level of support. Once the user encountered difficulty at any step of the problem-solving process, the amount of the support would be increased by one level for the current and the rest of the problem steps immediately. The teaching process proceeded until the user could solve two consecutive problems with the lowest level of support.

Full Support Condition (swung between levels of support 4 and 1)
This condition represents the support condition which has been used in many computer-assisted learning environments. The program first demonstrated the complete problem solving procedure in a full-support example. Then it gave another problem

with the least amount of support (i.e. symbolic support) as a test. Full support was a screen option which could provide immediate help if the user encountered any difficulty in the problem-solving process (see Figure 5). If the user did not ask for full support but made any mistake in any step of the problem solving procedure, the full support would be provided starting from the current problem step. The current problem would then be solved as an example, and the next problem would be presented with the least level of support as a test again. That is, the program support swung between the levels of full support and least support. The teaching process proceeded until the user could solve two consecutive problems with the least amount of support.

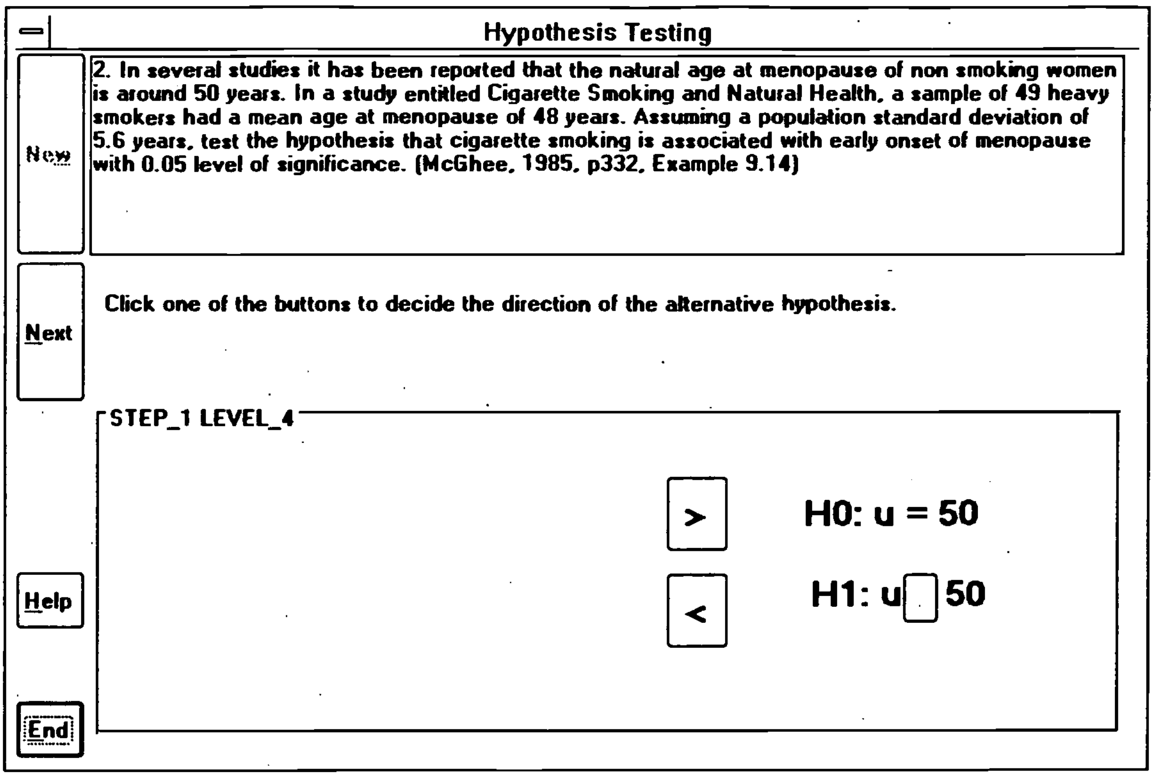

Figure 5. Full support was an on-screen option, “Help”, in the full support condition.

Least Support Condition (used level of support 1 once and thereafter level of support 4) This condition of program support represented the traditional teaching method which has been used in many statistic textbooks. It served as a control condition. As in the other two treatment groups, the program first explained the four steps of hypothesis testing procedure in a sample Z-test problem thoroughly (i.e. with full support). However, in the following problems, only the least amount of support (i.e. symbolic support) was provided. The user's responses in each step were judged for correctness at the end of each problem. If any mistake occurred in any step of the problem solving procedure, the correct answers were provided without explanation (see Figure 6). The process proceeded until the user solved two consecutive problems.

All conditions of the instructional program accessed the problems from a data file which contained 20 problems involving Z-test about one-tailed single sample mean.

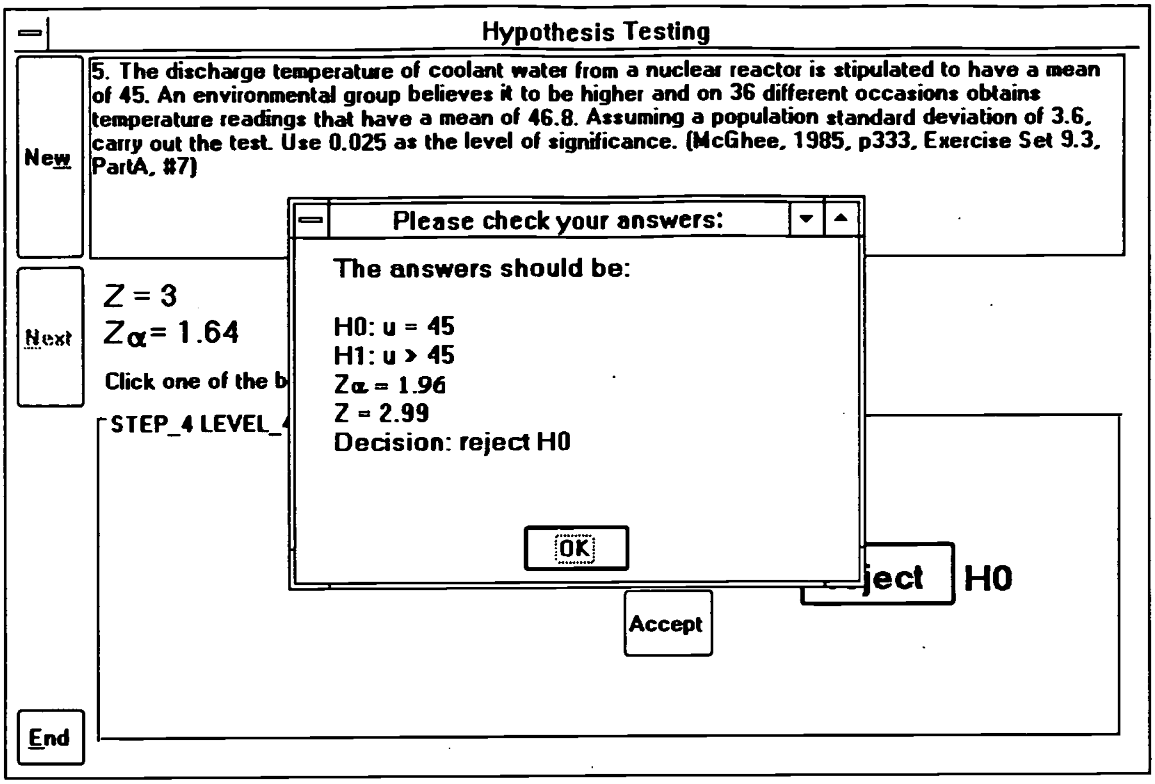

Figure 6. Correct answers were provided without explanation in least support condition.

2. Static Measure of the Learner's Ability (what the learner already knew)

   Related baseline factors in mathematics and statistics were considered. They were: courses taken in Mathematics (MATH_C), courses taken in Statistics (STAT_C), self-rating of mathematical skills (MATH_S), self-rating of statistical skills (STAT_S), mathematics preference (MATH_P), and statistics preference (STAT_P). In addition, the pretest score was also collected as a baseline measure of students' prior knowledge about the topic to be taught.

3. Dynamic Measure of the Learner's Ability (the learner's ability to learn)

   This measure was represented by the percentage of the successful trials where each problem step was considered as a trial after the first problem. For the scaffolded condition, as long as the learner provided a correct answer to the problem step, it was counted as a successful trial, no matter which level of support was provided.

   However, this indicator was not free from the influence of the treatments, the instructional condition, because:

   - Students in the least support condition had the chance to try and guess on the subsequent problem steps although a wrong answer had been provided.

   - Students in the scaffolded condition had the chance to retry on the same problem step and try on the following problem steps at higher support levels.

When a concomitant variable is affected by the treatment, covariance analysis will remove some (or much) of the treatment effect on the dependent variable (Neter, et al., 1985). To address this problem, two runs of the covariance analysis were conducted, one with dynamic measure, the other without. Therefore, the results of the two analysis could be compared and a more critical analysis could be made.

Response Variables

Two response variables were involved in this study. They were students' percentage correct on the maintenance posttest and transfer posttest.

Subjects

Subjects were 75 students enrolled in an introductory course of educational psychology at a major midwestern university in the fall semester of 1995. The majority of the students were juniors and sophomores in educational majors.

Prior to the study, the concepts of the normal distribution, standard deviation, and the Z-score were covered in the first 6 weeks of the course. Therefore, the materials of instructional program were relevant and appropriate to the students. The participation of the study was counted as two-hour research credits. Students were invited on a volunteer basis. Subjects were then randomly assigned into the three condition groups.

Among the 75 students, 3 students scored more than 80 percent of the total score on pretest. They were dropped from the analysis. Therefore, only 72 students (24 in full support group; 26 in scaffolded group; and 22 in least support group) were included in the analysis.

Instruments

All the tests were administered in paper-and-pencil format with a calculator and a copy of the Z-score table provided.

Pretest and Maintenance Posttest

Each test consisted of three problems involving a one-tailed Z-test of single sample means. Each problem consisted of four steps and each step involved at least three different subconcepts. A total score of 48 was possible.

Transfer Posttest

The transfer posttest contained one one-tailed and two two-tailed Z-test problems of single sample means. Each problem consisted of four steps and each step involves at least three different subconcepts. A total score of 48 was possible.

All the test problems were adapted from statistic textbooks and previewed by two experts in statistics.

Procedure

The experiment was conducted in the seventh to tenth weeks of the fall semester of 1995. It consisted of two sessions with 7 to 10 days in between. For better control of the experiment, the first session was conducted by one of the researchers.

Session One

Each participant first completed a participant survey at the beginning of the first session of the experiment. Then the participant was informed of the session agenda and the expected time spent on each activity. After that, the researcher checked the participant's ability to use a computer mouse and demonstrated the skill if necessary. Before working on the computer, the participant was provided with a hand-held calculator, a Z-score table, and a couple of worksheets for notetaking and calculation. The participant could keep and use these tools for the entire session. The participant then started to work on computer-based pre-instruction for about 20 minutes. The pre-instruction reviewed all of the prerequisite skills and knowledge needed for the major instruction. Then, for 10 minutes, the participant completed a self-evaluation over the key concepts learned in the pre-instruction by working on the paper-and-pencil prerequisite test. A key with detailed explanation was provided. After the prerequisite test, the participant was given a three-problem pretest. The participant was told at the beginning that he/she was not expected to know the answers to these problems. If having spent more than three minutes on one problem but was unable to proceed, he/she could quit the pretest there. The expected time for the pretest was 10 minutes. After completing the pretest, the participant went back to the computer and worked on the major instruction for 45 minutes.

The major instruction started with a short introduction to the lesson environment. After that, the program demonstrated a step by step procedure to carry out a Z-test in a problem example. Then, the participant encountered a series of similar problems requiring him/her to provide the answers step by step. Along with these problems, one of the program support conditions (scaffolded, full support, or least support) was applied, depending on which condition group the participant had been assigned into. The program could not be terminated until the participant solved two consecutive problems with the least amount of support. However, the researcher would ask the participant to stop if he/she had spent more than 45 minutes on the major instruction and not finished. During the instruction, the participant could use the Z-score table at hand or a version of the table available on the computer. The participant's learning path and responses were recorded in a computer file for later retrieval. The number of problems the participant went through either to mastery or by reaching the time limit was noted.

Session Two

The second session was held about 7 to 10 days after the first. Each participant first was asked to complete the three-problem maintenance posttest for about 20 minutes. After the test, a one-page instruction on two-tailed Z-test was provided. After 10 minutes, the instruction sheet was taken away, and the three-problem near transfer posttest was administered. Again, the subjects could work on the test for 20 minutes. Upon completion of the test, the solutions to all the test problems were provided to the subject.

Data Analysis and Results

Covariance analyses were used to examine the main effects of the instructional method, the static measures of the learners' ability, and the dynamic measure of the learners' ability. Partial correlation and correlation analyses were used to examine the relationships among the static measures, the dynamic measure, and the treatment.

Results of Covariance Analysis

The Effect of the Instructional Method

1. The results of covariance analysis indicated a significant group difference on the maintenance posttest ($F = 4.03$ w/o and $F = 3.98$ w/ dynamic measure, $p < .05$). The

post hoc pairwise t-test showed no significant difference between the full support group and the least support group at the .0167 experimentwise or the .05 comparisonwise significance level. Therefore, the availability of full support in the computer-assisted instruction did hamper learners' independent problem-solving on the maintenance posttest.

2. The post hoc pairwise t-test showed that students in the scaffolded group performed significantly better than the other two groups on the maintenance posttest at the .0167 experimentwise significance level ($\underline{t} = 2.75$ w/o and $\underline{t} = 2.82$ w/ dynamic measure). Therefore, the scaffolded computer-assisted instruction did enhance learners' knowledge maintenance.

3. No significant group difference was found on the transfer posttest at the $\underline{p} = .05$ level.

The Effect of the Static Measure of the Learner's Ability

1. Only the pretest produced a significant effect on the maintenance posttest ($\underline{F} = 6.53$ w/o and $\underline{F} = 5.88$ w/ dynamic measure, $\underline{p} < .05$).

2. The transfer posttest score was significantly influenced by the pretest ($\underline{F} = 6.36$ w/o and $\underline{F} = 6.14$ w/ dynamic measure), the statistics courses taken before ($\underline{F} = 4.76$ w/o and $\underline{F} = 4.74$ w/ dynamic measure), and the learner's self-rating of mathematical skill ($\underline{F} = 6.97$ w/o and $\underline{F} = 5.57$ w/ dynamic measure) at the .05 significance level, suggesting that the learners who got higher scores on pretest, showed more confidence in mathematical skills, or took more and higher-level statistical courses performed better on the transfer posttest.

The Effect of the Dynamic Measure of the Learner's Ability

1. The effect of the dynamic measure was marginally significant on the maintenance posttest at the .05 level of significance ($\underline{F} = 3.89$, $\underline{p} = .0531$), indicating that the learners who showed higher ability to learn in the problem-solving process did maintain the strategy better.

2. The effect of the dynamic measure reached the .05 significance level on the transfer posttest ($\underline{F} = 3.89$). Therefore, the learners who showed higher ability to learn in the problem-solving process also transferred the strategy better.

Results of Partial Correlation and Correlation Analysis

The Relationship Between Static/Dynamic Measure and Treatments

The predictive utility of the static and dynamic measures varied in the three support conditions: scaffolded, full support, and least support.

1. The static measure predicted the students' posttest scores well in the full support condition ($\underline{pr} = .51$ for maintenance and $\underline{pr} = .50$ for transfer, $\underline{p} < .05$).

2. The static measure predicted the students' posttest scores best in the least support condition, but only the results for the transfer posttest were statistically significant ($\underline{pr} = .58$, $\underline{p} < .01$).

3. The dynamic measure predicted the students' posttest scores best in the scaffolded condition ($\underline{pr} = .40$ for maintenance and $\underline{pr} = .45$ for transfer, $p < .05$).

The Relationship Between Static Measure and Dynamic Measure

There was a strong relationship between the static measure and the dynamic measure, $r = .32$, $p < .01$. This was especially true in the least support group, $r = .63$, $p < .01$. This result suggests that the students' prior knowledge did influence their ability to learn, especially in the least support condition.

Discussion and Conclusions

The Instructional Methods

The results of this study confirmed the concern proposed by the Cognition and Technology Group at Vanderbilt University (1993) that individuals might over-rely on support in a computer environment. The availability of full support in the computer-assisted instruction did hamper learners' performance on the maintenance posttest. Although the group difference on the transfer posttest did not reach the level of statistical significance, the full support group got the lowest mean score. This suggests that students getting the full support all of the time might have over-relied on the available support. Therefore, they might have failed to develop their own internal mental model-building skills, so that they did not perform well when they encountered a similar but new learning situation. Also, the full support group had the largest standard deviation on both posttest scores. This means that the effect of this instructional method tended to vary by individual. Students' performance in the full support condition may have been more related to their original background knowledge than to instructional factors. On the other hand, the results of the study showed that scaffolded computer assisted instruction was superior to the non-scaffolded instruction in enhancing knowledge maintenance and reducing individual differences.

Although the findings confirmed the superiority of the scaffolded instruction, two results differed from the expectations. They were:

1. All the three groups had better performance on the transfer posttest when compared to the knowledge maintenance posttest. No statistically significant group differences were found on the transfer posttest.

2. The least support group (the control group) got a higher mean score than the full support group on the transfer posttest, although this difference did not reach the statistical significance level.

The differences between the maintenance and transfer posttests provide some possible explanations of the first unexpected result.

1. First of all, the maintenance posttest tested for knowledge retention. The transfer posttest, on the other hand, tested for immediate learning; memorization may have played a role in students' superior performance on the transfer posttest.

2. The transfer posttest used two-tailed tests which involved the same four steps as the one-tailed tests. Further, the transfer posttest was administered right after the maintenance posttest. The students had just spent mental effort trying to access the retained knowledge from their own mental models. The effect of the post-instruction therefore might have been in-time and significant.

3. The two-tailed tests did not involve deciding the direction of the alternative hypothesis. However, that's a crucial concept in the one-tailed tests. Many students indicated that they felt the two-tailed cases were easier than the one-tailed cases.

Beyond the above factors, there is still another possible explanation. That is the treatment condition may promote direct learning but not transfer. Although the scaffolded group got the highest mean score on the transfer posttest, the evidence was not strong enough to conclude that this scaffolded computer-based instruction can promote knowledge transfer. It still requires further research to verify this point.

To provide possible explanations for the second unexpected but interesting finding, an examination of the differences between the natures of the three instructional methods is required. Because the 3-D contingent scaffolding model introduced one more dimension into the scaffolding model by dividing the target task into a sequence of sub-tasks, the complexity of the group differences was increased. Table 2 compares the three instructional methods from three different aspects: chance to retry the same step, chance to guess on the following step, and immediate feedback on correctness.

Table 2

Group Differences on Chance to Retry, Chance to Guess, and Immediate Feedback

	Full Support	Scaffolded	Least Support
Chance to Retry the Same Step	N	Y	N
Chance to Guess on the Following Step	N	N	Y
Immediate Feedback on Correctness	Y	Y	N

Note. N = no. Y = yes.

The influence might be significant whenever the student provided a wrong answer:

1. In the full support condition, full support was provided right away whenever the learner failed to answer correctly. However, once the student realized that he/she had provided a wrong answer, the student tended to skip the explanation and answers to the rest of the problem steps and tried the same step in the next problem. Therefore, students might only have seen broken pieces of the statistical reasoning and hence lost the whole picture of the problem-solving procedure.

2. On the other hand, students in the least support group did not know they had made a mistake until end of the current problem. In this way, the learner more likely generated his/her own reasoning of the problem-solving procedure from the first to the last steps without any interruption. Besides, since the learner only received the least level of support, the learner had to spend more mental effort to figure out the answer to each problem step.

3. Students in the scaffolded condition had the chance to retry the same problem step with a higher level of support right away following an error. The learner not only could work on the same step that he/she had focused his/her interest on but also had more

support and therefore a better chance to succeed. Students had to spend a fair amount of the mental effort and still saw the whole picture of the problem-solving procedure. This might also be one of the reasons that made the scaffolded group proved to be superior to the others.

The Static Measure of the Learner's Ability

The results of the covariance analysis showed an influence of the pretest consistently across posttests, indicating that the pretest score was a very good predictor of the posttest scores. However, most of the students did not have any prior knowledge of the target learning task (applying the Z-test) except for the very basic statistics concepts taught in the introductory course (such as normal distribution and standard deviation). The results revealed that the understanding of these very basic concepts (which was reflected on the pretest score) might actually improve the learner's statistical reasoning on the learning task (which was reflected on the posttest scores).

The results showed no significant effect on the maintenance posttest of any of other baseline variables. Since the maintenance posttest score was not affected by the learner's mathematical background, students with low mathematical skills could benefit from the instruction. Similarly, the finding of no significant effects of learners' statistical background on maintenance posttest scores also showed that the content could be taught to statistical beginners. For the transfer posttest, only the courses taken in statistics and the self-rating of mathematical skills showed significant effects. This result suggests that students having more statistics background and feeling more confident about their mathematical skills, transferred the learned skill to the new learning situation better.

The Dynamic Measure of the Learner's Ability

According to the results of the covariance analysis, the effect of the dynamic measure was consistent across posttests, indicating that the learner's ability to profit from the instruction in the learning process could also be a good predictor of his/her later posttest performance. Since the indicator used (the percentage of successful trials) was affected by the treatment, the dynamic measure was not directly comparable across the three treatment groups.

Static/Dynamic Measure and Treatments

The results from the partial correlation analyses indicated the predictive utility of static and dynamic measure did vary by treatment, which confirmed other studies' conclusions (Burns, 1985; Day & Cordon, 1993). The result from the correlation analysis on static and dynamic measures was also consistent with Day and Cordon (1993). The results suggest that students' prior knowledge (static measure) might influence the students' ability to profit from the instruction (dynamic measure), especially in the least support condition. Because this relationship was not significant in the scaffolded condition, and the dynamic measure was the best predictor in that group, the study results also suggest that scaffolded instruction could be the better diagnostic method when the goal is to obtain a measure of learning capability relatively uncontaminated by existing individual differences.

Conclusions

While the term "scaffolding" has been used widely in recent years in the field of media assisted instruction to emphasize its support-building component, this study showed the importance of its support-fading component. It used a 3-D model to demonstrate how the two components interact and compensate each other through the control of the amount of support as well as the task. In this study, the 3-D contingent scaffolding model was discussed, implemented, and evaluated in a computer-based instruction application, "Hypothesis Testing-- the Z-Test," in order to establish baseline data for integrated-media-based instruction and hypermedia-based learning environments. The conclusions are:

1. This model can be successful in promoting learning as well as enhancing learners' independent knowledge application. The results of this study not only confirmed the problem of learners over-relying on technology support but also showed that the 3-D scaffolding model can be the solution to this problem. However, further evidence is needed to confirm its superiority on knowledge transfer.

2. This model provides a systematic way to link the concept of scaffolding to the integrated media design features using both support building and fading techniques. The results of this study showed that the computers and hence the integrated media could be a good vehicles to employ the 3-D model of scaffolding.

3. This model promotes learning consistently across individuals. The dynamic measure of the learner's ability was a better predictor of the learning outcome for this scaffolded instruction than were the static measures. If the goal is to obtain dynamic measures that predict the learning outcome and that are relatively uninfluenced by pre-existing individual differences, the dynamic measure collected during scaffolded instruction may be the superior diagnostic method.

4. This model was implemented well on the topic of hypothesis testing. The results of this study also showed that the topic of hypothesis testing could be taught to the students with low mathematical background and statistics beginners.

This study serves as an example of an integrative effort which combined constructivist learning theory, statistical problem solving, and CAI design principles. The results of the study showed the value of the 3-D scaffolding model on CAI design in helping college students construct, test, and refine their understanding of complex statistical reasoning. A similar model could be adapted to other integrated media learning environments, to various disciplines, and to different audiences.

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